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EPA

SITE
SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

Technology Demonstration Summary

The American Combustion Pyretron Thermal Destruction System at the U.S. EPA's Combustion Research Facility

Under the auspices of the Superfund Innovative Technology Evaluation, or SITE, program, a critical assessment was made of the American Combustion Pyretron™ oxygen enhanced burner system during eight separate tests at the United States Environmental Protection Agency's Combustion Research Facility (CRF) in Jefferson, Arkansas. The report includes a description of the Pyretron and of the facilities used at the CRF, the tests conducted as part of this demonstration, the data obtained, and an overall performance and cost evaluation of the system.

Results show that Destruction and Removal Efficiencies (DREs) of 99.99 percent were achieved for a series of polycyclic aromatic hydrocarbons found in decanter tank tar sludge, RCRA listed waste K087, the organic waste tested during this demonstration. Particulate emissions of less than 180 mg/dscm at 7 percent 0_2 were measured for all tests. The use of oxygen enhancement with the Pyretron enabled the feed rate of the waste to be doubled. All solid and liquid residues generated during these tests were contaminant free. The costs associated with using the Pyretron in place of an air-only burner depend upon the relative costs of oxygen and fuel and to some extent the capital costs of the burners themselves. For this demonstration, operating the Pyretron with oxygen enhancement used oxygen worth between $3250 and $3870 (it was provided free of charge) and roughly $2672 worth of propane. Operation without oxygen enhancement consumed $4000 worth of propane. During this period 1820 kg of waste were treated using oxygen and 1180 kg were treated without oxygen. The Pyretron burners used in this demonstration had an estimated cost of $150,000 and involved $50,000 of design and development effort.

This Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the SITE program demonstration that is fully documented in two separate reports (see ordering information at back).

Introduction

The SITE demonstration of the American Combustion, Inc. Pyretron oxygen-enhanced burner system was conducted from November 16, 1987 to January 29, 1988 at the U.S. Environmental Protection Agency's Combustion Research Facility (CRF) in Jefferson, Arkansas. The Pyretron was installed on the CRF's Rotary Kiln Incinerator System (RKIS). This demonstration was conducted using a mixture of decanter tank tar sludge from coking operations (RCRA listed waste KO87) and waste soil excavated from the Stringfellow Superfund site near Riverside, California. These two wastes were mixed together to provide a feed stream that had high levels of organic contamination and was in a soil matrix. This was determined to be the best feed material to use to evaluate the performance of the Pyretron. The purpose of the demonstration tests was to provide the data to evaluate three ACI claims regarding the Pyretron system. These claims are as follows:

- The Pyretron system with oxygen enhancement reduces the magnitude of the transient high levels of organic emissions, CO, and soot ("puffs") that occur with repeated batch charging of waste to a rotary kiln.
- The Pyretron system with oxygen enhancement is capable of achieving the RCRA mandated 99.99 percent destruction and removal efficiency (DRE) of principal organic hazardous constituents (POHCs) in wastes incinerated at a higher waste feedrate than conventional, air-only, incineration.
- The Pyretron system is more economical than conventional incineration.

Process and Facility Description

Two Pyretron burners were installed on the RKS. One was installed on the kiln and one on the afterburner. Valve trains for supplying these burners with controllable flows of auxiliary fuel, oxygen, and air; and a computerized process control system were also provided. A schematic of the system as it was installed at the CRF is shown in Figure 1. The Pyretron burners use the staged introduction of oxygen to produce a hot luminous flame which efficiently transfers heat to the solid waste fed separately to the kiln. Oxygen, propane and oxygen-enriched air enter the burner in three separate streams each concentric to one another. A stream of pure oxygen is fed through the center of the burner and is used to burn propane in a substoichiometric manner. This produces a hot and luminous flame. Combustion is completed by mixing these hot combustion products with the stream of oxygen-enriched air.

All tests were performed in the RKS at the CRF. A simplified schematic of this system is given in Figure 2. The system consists of an 880 KW (3MM BTU/hr) rotary kiln incinerator, a transition section, a fired afterburner chamber, a venturi-scrubber and a packed-column scrubber. In addition, a backup air pollution control system consisting of a carbon-bed adsorber and a HEPA filter is installed downstream of the previously mentioned air pollution control devices. With the exception of the carbon bed and HEPA filter, the system is typical of what might exist on an actual commercial or industrial incinerator. The carbon bed and HEPA filter are installed to ensure that organic compound and particulate emissions to the atmosphere are negligible.

The waste incinerated during the SITE demonstration was a mixture of 60% decanter tank tar sludge from coking operations, RCRA listed waste KO87, and 40% contaminated soil from the Stringfellow Superfund site. The KO87 waste was included in the test mixture to provide high levels of several polynuclear automatic hydrocarbon compounds. Six of these, naphthalene, acenaphthylene, fluorene, phenanthrene, anthracene, and fluoranthene were selected as the Principal Organic Hazardous Constituents (POHCs) for the test program. The Stringfellow soil was included in order to make the resulting feedstream more closely resemble the type of waste that would be incinerated using this technology. For all tests the waste was packed into 5.7 L (1.5 gal) fiber pack drums. Each drum contained between 4.1 and 7.9 kg (9 and 17 lb) of waste.

Eight tests were performed. These tests were designed to compare oxygen enhanced incineration to air-only incineration using the Pyretron. Table 1 summarizes the test conditions for the eight tests conducted.

During each test the feed and all effluent streams were sampled and analyzed to determine levels of contamination. In addition levels of carbon monoxide, carbon dioxide, oxygen, total unburned hydrocarbons, and nitrogen oxides in the exhaust gas were continuously measured and recorded. Comparison of the stripchart recordings of the oxygen-enhanced and air-only operation made it possible to determine whether or not the controlled introduction of oxygen reduced transient emissions.

Results and Discussion

A detailed summary of the SITE demonstration test results is presented in Figures 3 and 4 that follow and in Tables 2 and 3. Based on the test objectives outlined in the Introduction, the following results were obtained and conclusions drawn.

Transient Emissions

American Combustion claimed that the Pyretron with oxygen enhancement could reduce the levels of transient emissions that occur when solid waste is batch charged to a rotary kiln. Transient emissions occur when organic contaminants originally present in the solid waste are volitalized in the hot kiln environment. The rapid volatilization and reaction of these organic contaminants depletes the kiln environment of oxygen. Pyrolysis occurs in the oxygen-depleted kiln environment. This results in the production and emission of soot and other pyrolysis products.

The basis for American Combustion's claim of reduced transient emissions is based upon the belief that the timed addition of oxygen would provide sufficient oxygen to the kiln atmosphere to oxidize the volatilized organic matter, thus reducing pyrolysis and the resulting emissions of pyrolysis products. The demonstration tests were planned to evaluate this claim by deliberately feeding the kiln in a way that would produce transient emissions and then by measuring and recording those emissions as carbon monoxide "spikes" on continuous emission monitor stripcharts. The stripcharts produced under air-only and oxygen-enhanced operation would be compared in order to determine any statistically significant differences in transient emissions between air-only and oxygen-enhanced operation.

Figures 3 and 4 show the stripchart data for tests 2 (air-only operation at 105 lb/hr feedrate) and 5 (oxygen enhancement at 210 lb/hr feedrate). These two figures are presented to indicate the frequency and level of transient emissions during the demonstration. All of the continuous emission monitor stripcharts obtained during the demonstration are presented in the Technology Evaluation Report. Comparison of the carbon monoxide emissions indicates that no significant differences in transient emissions could

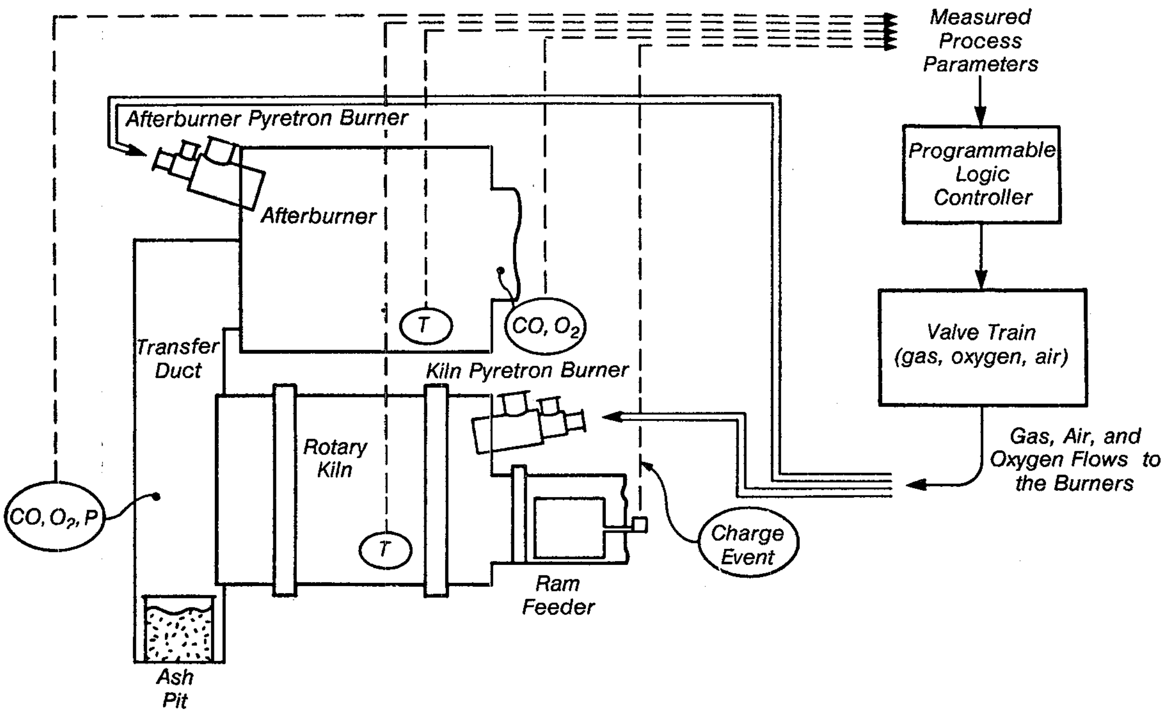

Figure 1. *Pyretron thermal destruction system process diagram.*

be readily observed. Statistical analysis of carbon monoxide peak height indicated that test-to-test variation was greater than the variation observed between air-only and oxygen-enhanced operation. Thus, it was not possible to state as a result of these tests whether the timed addition of oxygen reduced transient emissions.

There are two possible explanations for the inconclusive results of these tests. First, in order to achieve throughput increases with the Pyretron, water was injected into the kiln. This was not part of the original test plan, but was later deemed necessary in order to demonstrate throughput increases with high heating value waste. Even though water injection is a reasonable way to achieve throughput increases with high heating value wastes, the injection of water made it impossible to assess the ability of the Pyretron to reduce transient emissions through the timed injection of oxygen. An explanation of this is as follows.

Without the water, temperature excursions and other operational problems would have resulted from feeding high heating value waste (24.61 MJ/kg) to the kiln at elevated feed rates. Higher kiln temperatures are believed to increase transient emissions by driving more organic material off of the solid waste fed to the kiln. The use of oxygen often results in higher kiln temperatures. The added water reduced kiln temperatures and may have reduced them enough to reduce transient emissions over what they would have been had the Pyretron been used without water. Thus, had there been any statistically significant reduction in transient emissions, it would have been the result of the addition of water and not the timed injection of oxygen into the kiln atmosphere.

Secondly, Superfund wastes are very heterogeneous in nature. Even though these wastes were mixed prior to the start of testing, it is likely that significant variation in organic content existed from batch to batch during feeding. Variation in waste feed organic content may have also affected the variations observed in transient emissions. It was difficult to separate variations of this nature from variations resulting from the performance of the Pyretron. Studies of transient emissions are best carried out in a laboratory setting using specially prepared, and therefore uniform, surrogate wastes. Such a study was conducted on a smaller version of the Pyretron at the U.S.EPA's Air and Energy Engineering Research Laboratory. Results indicate that the elevated temperatures that result from the use of oxygen enhancement result in an increase in transient emissions despite the additional oxygen present in the kiln atmosphere. This study is described in more detail in the Applications Analysis Report.

Destruction and Removal Efficiencies (DREs) and Particulate Emissions at Elevated Feed Rates

Even at double the feedrate, no organic contamination was detected in all but one of the twelve stack samples taken. Table 2 summarizes the DREs achieved. It should be noted that for the waste treated in this demonstration, 136 L/hr of water had to be added to the system at the elevated feed rates in order to achieve an increase in throughput. This is because the waste feed had a heating value of

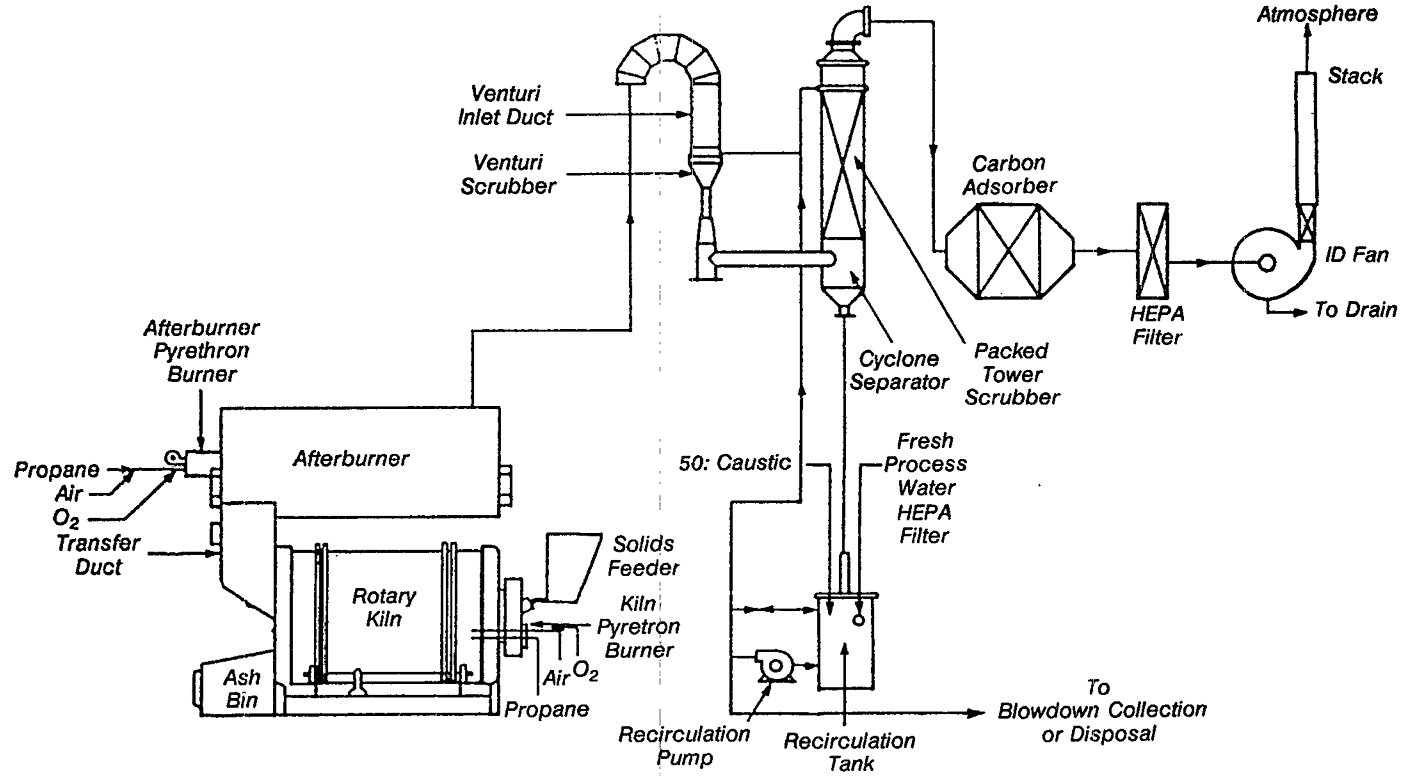

Figure 2. *CRF rotary kiln system.*

Table 1. *Summary of Demonstration Test Conditions*

Test		*Feed Rate*		*Kiln*			*Afterburner*		
No.	*Mode**	*kg/hr*	*(lb/hr)*	*Temp. °F*	*(C)*	*02, %*	*Temp. °F*	*(C)*	*02, %*
1	A	47.7	(105)	954	(1750)	13.3	1121	(2050)	7.7
2	A	47.7	(105)	921	(1690)	12.8	1121	(2050)	7.4
3	02	47.7	(105)	1035	(1895)	17.6	1121	(2050)	15.2
4	02	47.7	(105)	963	(1765)	14.5	1121	(2050)	15.0
5	02	95.5	(210)	979	(1795)	13.9	1121	(2050	14.0
6	02	95.5	(210)	979	(1795)	14.6	1121	(2050)	15.3
7	02	55	(120)	1010	(1850)	13.5	1121	(2050)	13.5
8	A	55	(120)	1010	(1850)	8.8	1121	(2050)	11.4

**A = Air only*
O2 = Oxygen enhanced

24.61 MJ/kg (10,400 Btu/lb). At the feed rates obtained with oxygen enhancement, this resulted in a total heat input of 640 KW (2.2MMBtu/hr). Without all of the nitrogen provided by air-only operation, an additional heat sink had to be provided. This problem would be alleviated when treating a lower heating value waste.

As indicated by Table 2, the stack gases were virtually free of organic contamination. The solid and liquid residues produced from these tests were also free of contamination. The composite scrubber blowdown liquor and kiln ash samples from each test were analyzed for the POHCs and other Method 8270 semivolatile organic hazardous constituents. No POHC was detected in any blowdown sample at a detection limit of 20 µg/L; no other

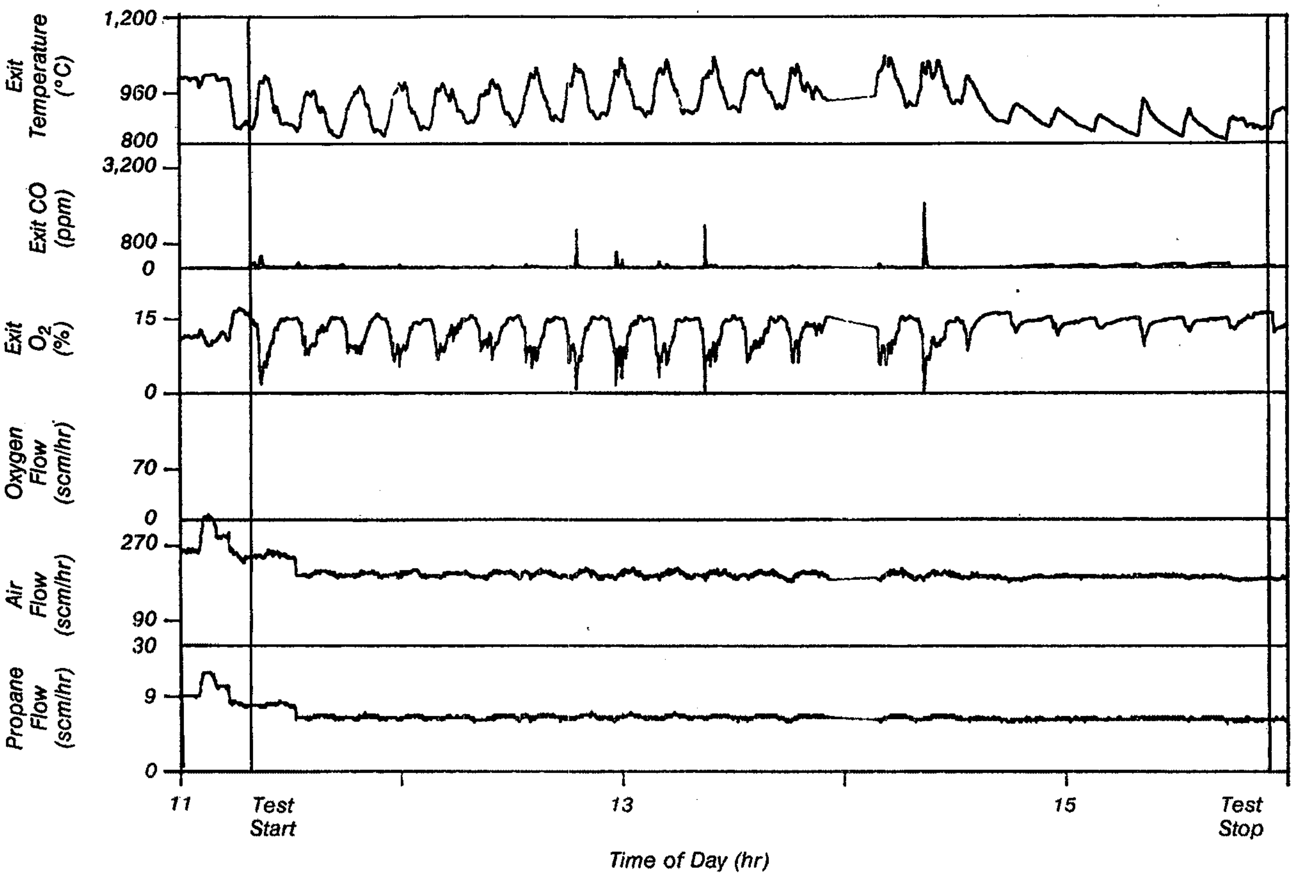

Figure 3. *Kiln data, Test 2.*

semivolatile organic hazardous constituent was detected at detection limits ranging from 100 µg/L (nitrophenols and pentachlorophenol) to 20 µg/L (all other Method 8270 constituents). No POHC analyte was detected in any kiln ash sample at a detection limit of 0.4 mg/kg ash. No other semivolatile organic hazardous constituent was detected at detection limits ranging from 2.0 mg/kg (nitrophenols and pentachlorophenol) to 0.4 mg/kg (all other Method 8270 constituents). This high level of decontamination is understandable given that all tests were performed at relatively high kiln and afterburner temperatures.

Particulate concentrations in the flue gas at the two locations sampled are summarized in Table 3. The two locations sampled were the scrubber discharge, and the CRF stack. Between the scrubber discharge and the stack are the carbon adsorber and the HEPA filter. Particulate levels were measured in the stack for all tests. Sampling port availability limitations precluded measuring scrubber discharge flue gas particulate emissions for the tests during which simultaneous MM5 sampling was performed (Tests 1, 2, 5, and 6).

The data in Table 3 show that particulate levels in the scrubber discharge flue gas for three Pyretron tests and one conventional incineration test were in the 20 to 40 mg/dscm at 7 percent O_2 range. All levels measured were below the RCRA incinerator performance standard of 180 mg/dscm at 7 percent O_2.

Costs

Since the Pyretron is a burner and, therefore, only one of many components of an incineration system, the use of the Pyretron can be expected to affect cost only incrementally. Since the capital cost for any burner is only a fraction of the capital cost for the entire incinerator, the majority of the costs associated with the use of the Pyretron will be associated with the costs of fuel and oxygen. Table 4 summarizes the costs for fuel and oxygen during the SITE demonstration. A range of costs is presented to give the reader an estimate of the variability in costs associated with using this technology. More information on costs is provided in the Applications Analysis Report on this demonstration.

The capital costs for the Pyretron system used in the SITE demonstration was $150,000. In addition $50,000 was spent in design and development work on the system.

Since this demonstration was done at a research facility and not under actual field conditions, the incremental effect that using the Pyretron has on the cost of incinerating a ton of hazardous waste cannot be directly determined. It is likely that the major factor in determining the cost effectiveness of the Pyretron will remain the oxygen and fuel. These costs

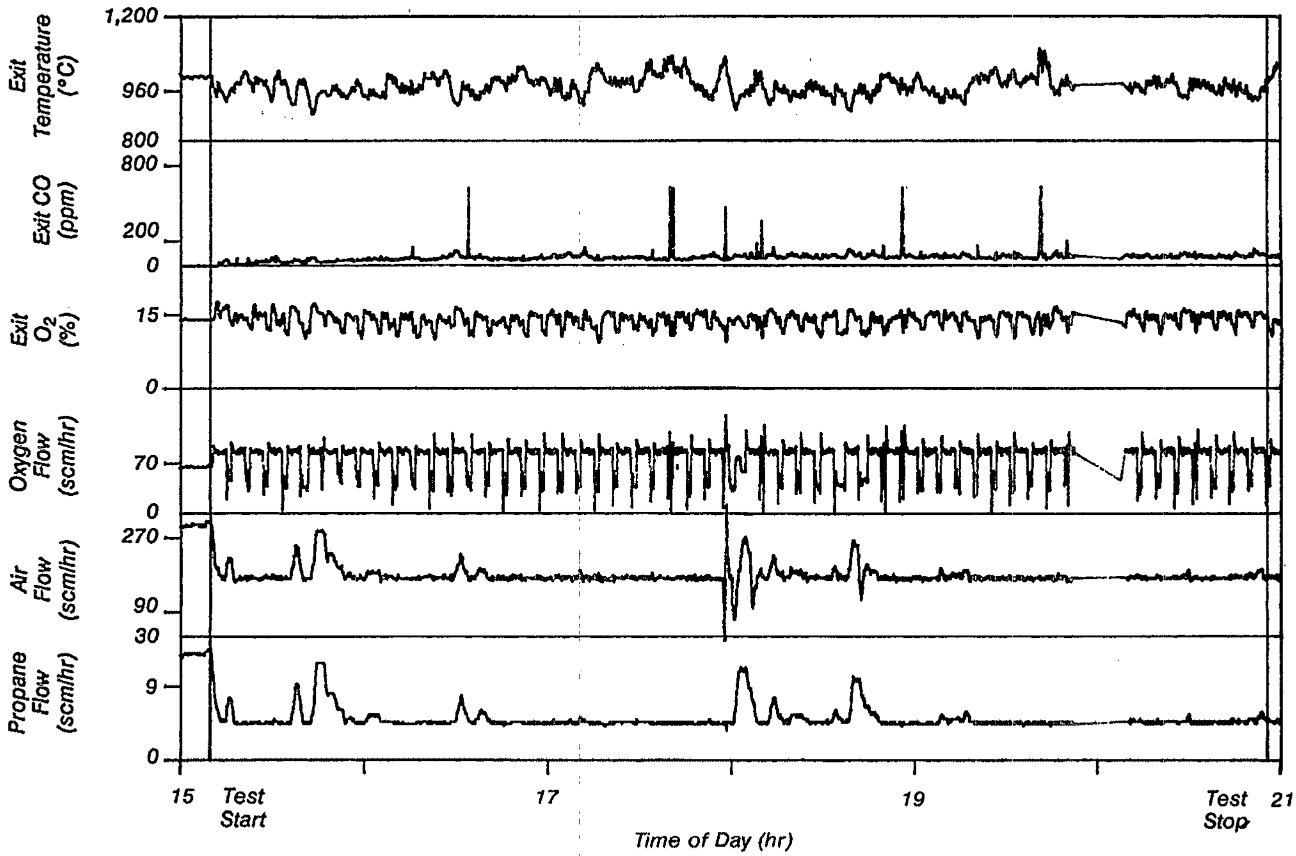

Figure 4. *Kiln data, Test 5.*

vary widely depending upon location and scale of operation. More discussion of costs is provided in the Applications Analysis Report.

Unit Problems

Three problems were identified with the Pyretron during the course of the SITE demonstration. First, EPA is not certain to what extent the Pyretron's process controller reacts to conditions within the incinerator. EPA was not provided with documentation on the control system. EPA's knowledge of how the control system operated during the demonstration is based on conversations with American Combustion personnel during the course of the demonstration. EPA's understanding of how the control system worked during the demonstration is as follows.

While the Pyretron allows for variation in the amount of oxygen fed into the incinerator during the course of a test run, the process controller requires that adjustments in the flowrate of oxygen be preset prior to the initiation of feed. During the SITE demonstration, the Pyretron's control system increased the oxygen level in a stepwise fashion to a series of preset levels if any one of the following three things happened:

1. Thirty seconds elapsed since the initiation of a batch feed cycle (which was indicated by activation of the ram feeder)
2. Carbon monoxide levels in the kiln exhaust reached a preset level. (undisclosed to the EPA)
3. Oxygen levels in the kiln exhaust reached a preset level (undisclosed to the EPA)

In the event that kiln pressure suddenly increased, the combustion air flowrate was reduced in a stepwise manner and the flow of oxygen was increased in order to keep the overall level of oxygen in the kiln constant. The initial and final levels of oxygen fed to the system were the same regardless of whether the stimulus was an elapsed time of 30 seconds or a carbon monoxide spike. Further, these levels were preset by the operator prior to the initiation of incineration and were based on the operators judgment as to the likely combustion behavior of the waste. This requires some prior knowledge about the way in which a given waste stream is likely to ignite and burn in the incinerator. This is difficult to ascertain unless that particular waste has been incinerated before.

Second, high heating value wastes are difficult to incinerate at elevated feed rates with oxygen enhancement. This is because when oxygen is added to the combustion air stream it displaces nitrogen. Without that nitrogen to act as a heat sink, the practical heat release limitations of the incinerator are soon reached when high heating value waste is treated. Additional heat absorption

Table 2. *Destruction and Removal Efficiencies (DREs)*

Test No.	Naphthalene	Acenaphthylene	Fluorene	Phenanthrene	Anthracene	Fluoranthene
1a	>99.9988	>99.9955	>99.9900	>99.9961	>99.9868	>99.9944
*	>99.9989	>99.9962	>99.9915	>99.9970	>99.9898	>99.9957
2a	>99.9989	>99.9954	>99.9905	>99.9971	>99.9904	>99.9955
*	>99.9940	>99.9739	>99.947	>99.956	>99.985	>99.931
3o	>99.9986	>99.9941	>99.9918	>99.9961	>99.987	>99.9926
4o	>99.99970	>99.9987	>99.9974	>99.99922	>99.9974	>99.9983
5o	>99.99985	>99.99942	>99.9988	>99.99968	>99.99896	>99.99932
*	>99.99987	>99.99952	>99.9990	>99.99972	>99.99909	>99.99941
6o	>99.99989	>99.99956	>99.9991	>99.99976	>99.99922	>99.99944
*	>99.99987	>99.99946	>99.9989	>99.99970	>99.99901	>99.99929
	Hexachloroethane	1,3,5 Trichlorobenzene				
7o@	99.9951	>99.9922				
8a@	>99.9926	>99.9865				

> indicates that the DREs are based on the analytical method detection limit
a = air, o = oxygen
** the second set of DREs are from duplicate samples*
@ tests 7 and 8 were done at the request of Region 9 and involve spiking Stringfellow soil with the two POHCs listed.

Table 3. *Particulate Emission Summary*

Test No.	Particulate Concentration (mg/dscm at 7 percent O_2)[a] Scrubber Discharge Flue Gas	Stack Gas
1 (12-9-87)	b	8
2 (12-11-87)	b	9
3 (12-17-87)	21	99
4 (1-14-88)	26	59
5 (1-20-88)	b	63
6 (1-21-88)	b	21
7 (1-27-88)	27	37
8 (1-29-88)	38	38

[a]Measured particulate concentration directly corrected to 7 percent O_2 using flue gas O_2 level. RCRA standard is 180 mg/dscm corrected to 7 percent O_2. This does not provide a direct comparison for tests with O_2 enhancement (Tests 3, 4, 5, 6, and 7).

[b]Denotes measurements not performed. Particulate levels increased at the stack partly because of particulate entrainment downstream of the scrubber discharge.

capacity must be provided if throughput is to be increased with this kind of waste. During this demonstration water was used. This was sufficient for the 24.16MJ/kg (10,400 Btu/lb) waste treated during the demonstration. In some situations, however, water injection may not provide sufficient heat absorbing capacity. In these cases throughput increases may be difficult to achieve.

Third, levels of NO_x produced by the Pyretron were elevated over those that occurred without oxygen enhancement. The high flame temperatures that result when the Pyretron is used with oxygen enhancement are responsible for this. Air-only operation resulted in average NO_x levels of 92 ppm. Use of the Pyretron with oxygen enhancement resulted in average NO_x levels of 1073 ppm. Appendix C of the Technology Evaluation Report contains all of the NO_x data obtained during the demonstration. The Applications Analysis Report discusses the implications of the Pyretron's high NO_x levels.

Conclusions and Recommendations

Based on the results and experience obtained from this SITE demonstration, the following conclusions and recommendations can be made concerning the operation and performance of the American Combustion Pyretron oxygen-enhanced burner.

1. Overall, the Pyretron may be useful in increasing the efficiency of incinerators that are treating many of the wastes that are found at Superfund sites.

2. With respect to the first claim made about the Pyretron, we were unable to conclusively determine whether the Pyretron system with oxygen enhancement was able to reduce the magnitude of transient emissions produced when waste is batch charged to a rotary kiln. Part of the reason for this is that the waste feed was not uniformly contaminated with high levels of organic waste. Because of this, variations in the levels of transient emissions observed could not be solely attributed to the action of the Pyretron. Further, there was not a clear difference in the frequency or level of transient emissions produced by the Pyretron with oxygen enhancement over conventional incineration.

3. As for the second claim made about the Pyretron, the demonstration clearly showed that thorough waste decontamination can be obtained at throughput rates double those achievable without oxygen enhancement provided that sufficient heat absorption capacity is provided when high heating value wastes are treated.

4. As for the third claim made for the Pyretron, the results of the demonstration indicate that the incremental cost of operating an incinerator equipped with the Pyretron will vary depending on the size and

Table 4. *Utility Costs Incurred During the Pyretron Site Demonstration*

Mode	Total Feed kg (lb)	Total Cost Oxygen $ HIGH LOW ACTUAL	Total Cost Propane $ HIGH LOW ACTUAL	Water Injection Cost $* HIGH LOW ACTUAL	Total Utility Cost $ HIGH LOW ACTUAL	Unit Cost $/kg ($/lb) HIGH LOW ACTUAL
Air	1180 (2596)	--	6000	--	6000	5.08 (2.31)
		--	3000	--	3000	2.54 (1.15)
		--	4008	--	4008	3.39 (1.54)
O_2	1820 (4004)	3870	4000	6.12	7876	4.32 (1.97)
		3250	2000	6.12	5256	2.89 (1.31)
		3560+	2672	6.12	6238	3.43 (1.56)

* only needed for high heating value wastes
\+ average value

location of the application as well as on the magnitude of the throughput increases achievable and is predominantly influenced by the costs of oxygen and fuel.

5. The NO_x levels observed during the demonstration may limit the applicability of the Pyretron in situations requiring stringent control of these emissions. Further development of the Pyretron may alleviate this problem.

*The EPA Project Manager, **Laurel J. Staley**, is with the Risk Reduction Engineering Laboratory, Cincinnati, OH 45268 (see below).*

The complete report, entitled Technology Evaluation Report, Site Program Demonstration Test: The American Combustion Pyretron Thermal Destruction System at the U.S. EPA's Combustion Research Facility," (Order No. PB89-167894/AS; Cost $28.95, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
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Telephone: 703-487-4650

A related report, which discusses application and costs, is under development.

The EPA Project Manager can be contacted at:
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